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THE ROLE OF TECHNOLOGY COMPANIES IN REDUCING AND DISPOSING FOOD WASTE

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ABSTRACT

This study aims to identify what innovative technological solutions companies offer to reduce avoidable and unavoidable food waste and how successful these solutions are. The data in the study were obtained through document analysis, a qualitative research method. Within the study's scope, case studies and information from the websites of sixteen firms providing technological solutions for minimising avoidable food waste and nine firms providing technical solutions for unavoidable food waste disposal, alongside news articles and academic research about these firms, were analysed. Companies offer technological solutions to prevent food waste by tracking, analysing, and reporting it directly. Companies also have indirect technological solutions to prevent food waste, such as accurate sales forecasting, production planning, menu analysis, inventory management, production enhancement, temperature monitoring, and risk analysis. The study showed that the innovative solutions offered by technology companies for hotels, restaurants and catering companies directly and indirectly successfully reduce food waste. The study also revealed that companies can improve sales forecasting, production planning, and operational processes and reduce food and labour costs using technology solutions. The study also underlined that technology companies have different ways to deal with unavoidable food waste, such as turning it into energy, making new products, finding new ways to sell it, and using new composting methods.

Keywords: Avoidable Food Waste, Unavoidable Food Waste, Innovative Technological Solutions, Technology Companies

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TEKNOLOJİ ŞİRKETLERİNİN GIDA ATIKLARININ AZALTILMASI VE BERTARAF EDİLMESİNDEKİ ROLÜ

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ÖZET

Bu çalışma, şirketlerin önlenebilir ve önlenemez gıda israfını azaltmak için hangi yenilikçi teknolojik çözümleri sunduğunu ve bu çözümlerin ne kadar başarılı olduğunu belirlemeyi amaçlamaktadır. Çalışmada veriler, nitel araştırma yöntemlerinden doküman analizi yoluyla elde edilmiştir. Çalışma kapsamında, önlenebilir gıda atıklarını en aza indirmek için teknolojik çözümler sunan on altı firmanın ve önlenemez gıda atıklarının bertarafi için teknik çözümler sunan dokuz firmanın web sitelerindeki vaka çalışmaları ve bilgiler ile bu firmalarla ilgili haber ve akademik araştırmalar analiz edilmiştir. Şirketler gıda atıklarını takip etme, analiz etme ve raporlama yoluyla doğruda gıda israfını önlemeye yönelik teknolojik çözümler sunmaktadır. Şirketler ayrıca doğru satış tahmini, üretim planlama, menü analizi, envanter yönetimi, üretim iyileştirme, sıcaklık izleme ve risk analizi gibi gıda israfını önlemeye yönelik dolaylı teknolojik çözümlere de sahiptir. Çalışma sonucunda, teknoloji şirketlerinin otel, restoran ve catering şirketleri için sunduğu yenilikçi çözümlerin doğrudan ve dolaylı olarak gıda israfını başarılı bir şekilde azalttığı görülmüştür. Ayrıca çalışma sonucunda şirketlerin teknoloji çözümlerini kullanarak satış tahminlerini, üretim planlamasını ve operasyonel süreçleri iyileştirebileceğini, gıda ve işgücü maliyetlerini azaltabileceğini ortaya konulmuştur. Bunun yanında çalışmada teknoloji şirketlerinin kaçınılmaz gıda atıklarıyla başa çıkmak için gıda atıklarını enerjiye dönüştürmek, yeni ürünlere dönüştürmek, yenilikçi satış yöntemleri ve modern kompostlama yöntemleri gibi farklı çözüm yolları olduğunun altı çizilmiştir.

Anahtar Kelimeler: Önlenebilir Gıda Atıkları, Önlenemez Gıda Atıkları, Yenilikçi Teknolojik Çözümler, Teknoloji Şirketleri

INTRODUCTION

According to the World Food Programme (WFP) (2020), a third of the global food produced for human consumption is lost or wasted. This amounts to around 1.3 billion tonnes yearly, valued at one trillion dollars. This corresponds to 17% of worldwide food production (Mouysset, 2023). The hospitality sector generates approximately 18% of this food waste (Li et al., 2022). Every restaurant globally produces an average of 10,000 kg of waste annually. The hospitality sector generates 150 million kilos of food waste annually (Stouthamer and Singh, 2023). Moreover, the Boston Consulting Group predicts that food waste and loss will increase to 1.5 billion tonnes valued at £2.1 trillion by 2030 (Hegnsholt et al., 2018).

Zrnić et al. (2022) categorised food waste generated in the hospitality industry into two categories depending on whether it occurs before or after consumption by guests. Pre-consumer food waste occurs during the purchase, storage and preparation of ingredients. Food left on the plate constitutes post-consumer waste (Lipinski et al., 2013). Consumer-induced food waste is mainly behavioural, whereas food losses/degradation originate systemically (Parfitt et al., 2010). Principato et al. (2018) revealed that 12.93% of the restaurant's food was wasted due to spoilage and incorrect preparation, while 15.83% resulted from customer behaviour. Furthermore, Martin-Rios et al. (2018) divided food waste into two categories: avoidable and unavoidable. They claimed food waste was generated in three areas: front office, kitchen, and storage. Avoidable food waste is plate waste and unsold food (buffets) in the front office. Avoidable food waste in the kitchen includes poor cold chain management, water and cooking food (e.g., burned food), and food spoilage. Inventory (overstocking), and production methods and storage also cause avoidable food waste in storage. Unavoidable food waste is non-edible waste (peelings, bones, skins, shells) in the front office. Other food waste reasons for kitchens include manufacturing of packaging defects and unavoidable preparation waste. Food scraps and deficiencies in packaging and equipment also induce unavoidable food waste in storage.

Previous studies showed that measures can reduce food waste, which may result from conscious consumer decisions or systemic issues. For instance, reducing plate size can lower food waste by 19.5% (Kallbekken and Sælen, 2013), providing different menu options can reduce it by 55%-70% (Berkowitz et al., 2016), and displaying informative and warning posters can reduce it by 15%-19% (Dölekoğlu and Var, 2016). Filimonou et al. (2021) also demonstrated that implementing improved demand forecasting methods, purchasing smaller amounts of food with greater frequency, and practising portion control can prevent up to 28% of food waste. Furthermore, Matzembacher et al. (2020) determined that food waste is less if customers take their meals themselves according to three different service types.

Adopting technology within the hospitality industry can deliver measurable improvements in efficiency, accuracy and safety, as well as a significant decrease in food waste. Digital sensors and thermometers allow precise storage and cooking temperatures, with the ability to signal any malfunctions or temperature variations, such as a door being left open. Automatic inventory management guarantees accurate and timely orders. Based on sales reports, customer demand forecasts can be more precise by analysing data such as the best-selling products and product demand densities and managing personnel resources more efficiently. Additionally, technology can simplify product preparation processes and enrich menu content according to customer preferences (Suri and Helfand, 2019). So, technology can significantly reduce food waste and offer considerable advantages. In this study, the services provided by companies offering innovative technological solutions for monitoring, analysing and reporting food waste and their roles in reducing it were analysed. Moreover, companies providing various solutions for disposing of unavoidable food waste were assessed.

LITERATURE REVIEW

Adopting technology in the food service industry decreases waste and provides businesses with actionable measures to reduce food waste. Restaurant owners and executive chefs can make data-driven decisions to optimize business practices by tracking progress on reduction targets (Martin-Rios et al., 2021: 7). According to FAO (2018), food waste can occur at each stage of the food supply chain, including procurement, storage, production, and consumption. Therefore, any technological advancements made along this chain are beneficial in preventing food waste from happening in all areas. Artificial intelligence (AI) and machine learning (ML) not only increase customer satisfaction with the ability to offer personalised ordering but also improve employee productivity with fewer production errors, the right amount of preparation and fast service (Kumar et al., 2021). Executive chefs also gain access to an online analysis dashboard that provides them with in-depth knowledge of food waste components, quantities, costs and sources of waste (Martin-Rios et al., 2021). Furthermore, the employment of mobile workflow applications and digital temperature sensor technologies can substantially enhance their kitchens' efficiency, safety and profitability, with the added benefit of diminishing food safety hazards and averting food waste (Suri and Helfand, 2019). In addition, the move towards automated inventory management allows for more accurate forecasting of customer demand and trends, real-time monitoring of current stock levels, and automated ordering. This reduces the likelihood of inaccurate orders and minimises food waste resulting from spoilage (Dougherty, 2023).

In the hospitality sector, failures, including overproduction, cooking errors and leftovers, account for 8% to 20% of the total food cost. By curtailing food waste, the hospitality industry can not only minimise avoidable food expenses but also reduce bills by shortening the usage time of kitchen appliances. Additionally, the improvement in cooking and serving enhances guest satisfaction and brand loyalty, and, as a result, occupancy rates increase over time (Pardo, 2021). In particular, eliminating avoidable food waste will enhance profitability by reducing food expenses for the business. Betz et al. (2015) found that 91.98% of the food waste produced by educational establishments and 78.14% made by private enterprises was avoidable. This led to avoidable costs of CHF 78,957 in the education sector and CHF 68,346 in the private sector. Papargyropoulou et al. (2016) discovered that 56% of the food waste generated by a hotel buffet service was avoidable. Dolnicar et al. (2020) carried out an experimental study utilizing a game-based approach with stamp collection and brochures. The findings yielded a 34% decrease in per capita plate waste amongst family members. It was reported that this implementation could lead to savings of £6,636 and £7,854 in food purchasing costs.

Different solutions have been developed to address unavoidable food waste. Hotels, restaurants, and theme parks can use on-site food waste composters for non-recoverable food. Composters can compost the food waste, which can be used for landscaping (Esposito, 2021). Sakaguchi et al. (2018) revealed that 84% of the 29 restaurants in Berkeley, USA, used compost bins to dispose of food waste. The study also showed that 72% of these restaurants distributed excess edible food to their employees.

In addition, certain cafes and restaurants may donate surplus food to charitable organizations after business hours (Solo Resource Recovery, 2023). Businesses that donate in this way can gain tax deductions (Esposito, 2021). Many countries, such as South Korea, Australia and the USA, have imposed wet waste taxes on the private sector to combat generalised waste generation. In addition to the direct economic loss caused by food waste costs, these businesses incur additional taxes for waste disposal and impositions on recycling. In other words, the hospitality industry is under increasing financial pressure to find a solution for food waste as soon as possible (Pardo, 2021). In addition, an alternative is to offer healthy and consumable foods at food and drink establishments at a reduced price towards the end of the day or during off-peak periods (Erik and Pekerşen, 2019).

Tourists exhibit responsible behaviour towards the environment and society and consider sustainability important. Technology encourages sustainability and environmental responsibility with less paper usage and food waste while enhancing the guest experience through accurate orders and efficient services (Dougherty, 2023). According to a survey by Booking.com (2021) of 3390 travellers from 29 countries, 83% of global travellers consider sustainable travel a vital factor. Additionally, 53% of travellers reported discomfort with staying in places that do not offer recycling facilities. Accommodation enterprises practising responsible and sustainable methods can increase their brand reputation and gain a competitive edge compared to their competitors (Pardo, 2021). Studies on technology's use in reducing food waste in literature are summarised below.

Martin-Rios et al. (2021) provided a comprehensive report based on three years of field data from 2017 to 2019, detailing one company's approach to measuring food waste and conducting an in-depth case study of Kitro, which offers automated food waste measurement technology. The data shows that reducing food waste can yield considerable benefits, with a potential reduction of up to 60% in avoidable food waste and cost savings ranging from £25,000 to £150,000 per person. All experts interviewed for the study noted that Kitro is a valid method for quantifying food waste and identifying operational inefficiencies and enhancing operations swiftly.

Çavuş (2021) conducted a content analysis of 23 applications designed to reduce waste and fight hunger. Despite their differing methods, the study found that all applications aim to prevent food waste and alleviate hunger. Furthermore, the research highlighted that these applications serve multiple purposes, including generating economic value, conserving energy and reducing food waste by linking stakeholders.

In their conceptual study, Stroumpoulis et al. (2021) investigated the advantages of applying blockchain technology to food supply chains to manage food waste. The study discovered that blockchain technology could facilitate efficient coordination of food supply chains, enhance food waste management, and curb food waste in the hospitality sector. The study showed that blockchain technology can potentially decrease the environmental impact of every stage within food supply chains.

Furthermore, businesses can enhance customer loyalty by adopting a green and eco-friendly business strategy. Lastly, blockchain technology may increase operational efficiency by decreasing transaction expenses.

Faezirad et al. (2021) proposed a new artificial neural network-based model based on machine learning to reduce food waste in a university cafeteria based on reservation data and students' behaviour at meal delivery times. The study provides a framework that can reduce food waste by up to 79% whilst also managing the associated costs of fines and waste. The model underwent cost analysis, and the results confirmed its efficacy in reducing the total cost.

Kumar et al. (2021) examined the prospects offered by artificial intelligence (AI) and machine learning (ML) technology in the food industry. Restaurants, cafes, and hotels can enjoy many benefits, such as optimised sales forecasting, personalised ordering, enhanced menu combinations, better food safety, lower incidence of human errors, reduced food waste, greater resource efficiency, and higher customer satisfaction by deploying AI and ML.

Leverenz et al. (2021) analysed breakfast buffet leftovers in four hotels in Germany as a case study to quantify the effects of self-reporting on food waste generated in hotel kitchens and the potential for waste reduction. The authors developed a food waste tracking system called Resourcemanager Food and tracked the food waste of the four hotels for 12 months. As a result of the study, breakfast buffet leftovers were reduced by 64.3% on average, associated with annual monetary savings of approximately 9000 Euros per kitchen.

Eriksson et al. (2019) analysed data on 735 hotels, restaurants and canteens in Europe, particularly in Sweden and Norway, using a spreadsheet, a dedicated scale or an internet-based service to monitor food waste. It was found that 61% of the catering units analysed had reduced their waste. It was also found that establishments using automated food waste monitoring tools like eSmiley, Matomatic, Visma, and Winnow were more effective in reducing food waste. Another study by Eriksson et al. (2017) utilised the Matomatic internet database and scale to assess the amount of food waste generated by municipal catering services in Sweden. The study showed that wasted food consisted of 64% serving waste and 33% plate waste.

Martin-Rios et al. (2018) analysed technological improvements in food waste and service management. They underlined that many companies are not innovating, even though they are increasingly aware of waste management's economic and social importance. The study emphasised that only a few companies serve as zero-waste restaurants. In another study by Martin-Rios et al. (2020), Kitro, which offers innovative technological solutions for food waste, was analysed as a case study from the perspectives of sustainability, innovation, strategy, sustainable entrepreneurship or hospitality operations management.

This study aims to identify what innovative technological solutions companies offer to reduce avoidable and unavoidable food waste and how successful these solutions are. Similarly, Çavuş (2021) examines a mobile app created to tackle food waste and hunger.

The original aspect of this study is the analysis of the web pages and case studies of companies offering artificial intelligence (AI), machine learning (ML), Internet of Things (IoT) and some other innovative technological solutions. In line with the aim of the research, answers to the following questions were sought:

RQ1: What technological solutions do companies offer to reduce the amount of avoidable food waste?

RQ2: How successful are companies offering innovative solutions in reducing avoidable food waste?

RQ3: What innovative solutions do companies offer to dispose of food waste that is not unavoidable?

METHOD

The data in the study were obtained through document analysis, a qualitative research method. Document analysis is a scientific research technique that entails gathering, reviewing, questioning and analysing various documents as the primary research data source (Sak et al., 2021). This method systematically analyses documents such as reports, video and audio recordings, files, and photographs related to the research topic (Karataş, 2015). Technology companies that offer innovative technological solutions to reduce food waste in hotels, restaurants and catering companies were included in the research through online research. In addition, technology companies that offer different and original solutions for food waste disposal were included in the study. The online research was conducted in July 2023. Within the study's scope, case studies and information from the websites of sixteen firms providing technological solutions for minimising avoidable food waste and nine firms providing technical solutions for unavoidable food waste disposal, alongside news articles and academic research about these firms, were analysed. The names of the relevant companies, their place and dates of establishment, their objectives and the success of the technological solutions offered by the company in reducing food waste are summarised in tables and interpreted descriptively. In this study, where the articles were reviewed through document analysis, no ethics committee approval or legal/special permission was required.

FINDINGS

This heading presents the analysis of information and case studies gathered from company websites, news and academic research papers. The focus is on the technological innovations the companies offer to reduce avoidable and unavoidable food waste and the effectiveness of these solutions.

Table 1 shows the names, places of establishment and dates of the companies offering technological solutions for avoidable food waste, the purpose for which the company provides a solution, and the successful results that the company has committed or measured for its resolution. Since food waste occurs at different stages, such as procurement, storage, production and consumption, technological solutions companies offer to prevent food waste also contribute directly or indirectly to preventing food waste. Orbisk, Kitro, Lumitics, Matomatic, Winnow Solution, Leanpath, and Light Blue provide technological solutions for monitoring, predicting, analyzing, and reporting food waste to prevent it directly. Companies also have indirect technological solutions to prevent food waste, such as accurate sales forecasting, production planning, menu analysis, inventory management, production enhancement, temperature monitoring, and risk analysis. The technological solutions provided by Clearcogs, Delicious Data, and Tenzo companies enhance food production planning, optimize personnel resource utilization, and increase operational efficiency by predicting sales and demand based on data. With its technology, Perfect Company can forecast production by considering many factors, such as content, quantity, preparation and cooking time, and create a labour plan and workflow according to the menu content. In addition, TotalCtrl and Lightspeed offer innovative inventory management systems, while Apicbase and Lumitics offer smart purchasing, inventory analysis and automatic order creation options. The technologies of Lumitics and Apicbase enable menu design and improvement of menu options based on customer preferences and seasonal trends, while Tenzo technology allows product profitability analysis. Lightspeed offers a kitchen monitoring system. Similarly, eSmiley offers digital opportunities for kitchen self-monitoring, risk analysis, and automatic temperature measurement. Furthermore, Monnit provides a sensor system that controls food temperatures and issues real-time warnings for possible risks, including temperature rises, open doors, and unusual motor activity.

According to the technological solutions companies provide, their success in reducing food waste varies. The highest success rates achieved by technology companies specialising in food waste reduction are Winnow Solution at 70%, Leanpath at 64%, Kitro at 60%, Orbisk at 50%, Matomatic at 50%, Light Blue at 43% and Lumitics at 30%. Among the companies offering sales demand forecasting and production planning technology, Clearcogs achieved 52%, Delicious Data 82% and Tenzo 80% food waste reduction. TotalCtrl, which offers an innovative inventory system, has achieved a 35% food waste reduction. The company eSmiley has accomplished a 50% decrease in food waste. Companies that offer sales/demand forecasting and production planning technology appear to be more successful in reducing food waste. With the technological solutions offered by companies, they reduce food waste on the one hand and achieve significant savings on the other. Using Winnow Solution's technological solutions, Four Seasons Resort Costa Rica saved £46,000, Novotel Warsaw Centrum saved €18,000, and Hilton Dubai Jumeirah saved $65,000 within a year.

The size of waste in large-scale projects reveals the importance of combating waste in social, economic and environmental terms. As a result of a project with Light Blue with ten hotels and restaurants, 124,295 meals (62,147 kg. food) were prevented from the landfill, and $209,793 was saved. Another project with Light Blue resulted in 49,020 kg of food (equivalent to 98,041 meals) and a cost reduction of £241,170 at eight Hyatt hotels. Technological opportunities offered by businesses also provide advantages such as food cost, labour cost, improving sales forecasting and production planning, labour productivity and improvement of operational processes. Perfect Company achieved a 24% reduction in food costs and Apicbase an 18% reduction. Perfect Company and Tenzo achieved a 20% and 15% decrease in labour costs, respectively. Delicious Data improved by 50% in sales forecasting and production planning and Tenzo by 30%. TotalCtrl has reduced the time spent on stocktaking by 50% with its inventory management system. While Tenzo achieved a 15% increase in labour productivity with its technology, Light Speed achieved a 40% improvement in operational processes.

Table 1: Information, Aims and Achievements of Companies Offering Technological Solutions to Reduce Avoidable Food Waste

Company Name/ Date of Establishment/ Headquartes	Company Purpose	The Success of the Company's Technological Solutions in Reducing Food Waste
Clearcogs, 2021, Philadelphia, Pennsylvania, United States.	- Clearcogs (2023) offers an artificial intelligence-supported demand forecasting software application to increase operational efficiency.	With the company's innovative solutions, - Goop Kitchen has reduced food costs by 2%. - By devising a plan for the hourly bread preparation in a bakery, the wastage of bread was decreased by 52%, resulting in a saving of £4,000 annually and £1,000 in labour costs (Clearcogs, 2023).
Orbisk, 2019, Utrecht, Netherlands	- Orbisk (2023) developed a food waste management system for the hospitality industry that monitors and predicts food waste using innovative technology and Artificial Intelligence (AI).	- Orbisk (2023) claims that with its solutions, restaurant, hotel, and café kitchens can reduce food waste by an average of 50% and save per year. - Average-sized restaurants can avoid up to 5,000 kg of food waste and save from €20,000 to €40,000 per year (Stouthamer and Singh, 2023).
Delicious Data, 2017, Munich, Germany	- Using artificial intelligence (AI), Delicious Data (2023) offers a technological solution for planning sales forecasts and food production by combining historical data from the kitchen, other business portion sizes, and customer demand (weather, holidays, etc.).	With the company's innovative solutions, - Delicious Data (2023) promises to improve sales forecasting and catering planning by 40% and reduce staff costs by 4%. It also claims to reduce food waste by 30% due to the overproduction of food in catering businesses. - Through the interaction of digital and internal planning measures, Bayer Gastronomie was able to save 12,600 meals and reduce food waste by 34% in 2021. - Apetito Catering was able to %50 better planning accuracy, %15 less food waste and %3,5 less use of goods. - Food waste at the serving counter was reduced from 71 g initially to 13 g per plate at Studierendenwerk Darmstadt, resulting in a savings of 1,565 meals and an 82% reduction in food waste (Delicious Data, 2023).

Kitro, 2017, Switzerland	- Kitro (2023) offers automated food waste collection, monitoring, and analysis solutions in AI-enabled food and beverage outlets.	- Kitro (2023) claims that with its technological solutions, edible food waste can be reduced by up to 60% and save between 2% and 8% of the annual food cost. - In the study carried out with hotels, restaurants, and canteens, using three-year measurement data from 2017-2019, the average reduction of avoidable food waste was found to be 20-50% in canteens, 25-60% in hotels, and 15-40% in restaurants (Martin-Rios et al., 2021: 9).
Lumitics, 2017, Singapore	- With the support of artificial intelligence, Lumitics (2017) offers innovative technological solutions such as smart tracking of food waste, smart purchasing, and menu preparation based on customer preferences and seasonal trends.	- Lumitics (2023) reports a 30% decrease in food waste and suggests that a reduction of 8% in food expenses can be attained.
TotalCtrl, 2017, Oslo, Norway.	- TotalCtrl (2023) offers an innovative inventory management platform for hotels, restaurants, care homes, schools and households. The platform reduces food waste and saves time and money.	With the company's innovative solutions, - Total Ctrl (2023) claims to reduce food waste by 35% and time spent on stocktaking by 50%. - The Los Tacos restaurant saves more than 100,000 euros a year (Engelsen, 2021).
Tenzo, 2016, London, England.	- With its artificial intelligence (AI) and machine learning (ML) technology, Tenzo offers solutions for recognizing the top-selling and most profitable products, optimizing staffing use, and generating more accurate sales forecasts by considering variables like weather, holidays, and events.	With the company's innovative solutions, - Tenzo (2023) claims a 15% increase in labour productivity and gross margin and an 80% reduction in wasted food. - An 80% reduction in food waste was achieved at The Vurger Co. restaurant. - Nando Restaurant achieved a 30% improvement in demand forecasting and a 15% increase in labour productivity. - In the Qoot restaurant, data-driven alterations to shift schedules led to a 15% reduction in labour costs (Tenzo, 2023).
Apicbase, 2014, Belgium	- Apicbase (2023) offers solutions to optimise menu design, improve menu options, and create automatic orders by integrating recipes, purchasing and inventory analysis.	With the company's innovative solutions, - Circus Kitchen achieved an 18% reduction in catering costs. - Bright Kitchen's achieved an 8% reduction in catering costs. - CitizenM hotels achieved a 2% reduction in food costs (Apicbase, 2023).
Matomatic, 2014, Sweden	- Matomatic (2023) offers digital solutions for measuring, analysing and reporting food waste in restaurants and canteens.	With the company's innovative solutions, - reduces plate waste by 50%. - At Tierps Kommun school, wasted food was reduced by 720 kg in 2019 (Matomatic, 2023)
Perfect Company, 2013, Vancouver, WA	- With Perfect Kitchen digital applications, the Perfect Company (2023) offers technological solutions for forecasting production (content,	- Restaurants using Perfect Company solutions have realised $24,000 lower food costs and a 20% reduction in food preparation labour costs by reducing food waste per establishment (Perfect Company, 2023).

	quantity, preparation and cooking time), automatic planning according to menu content, providing staff workflow, and monitoring portions and food waste.	
Winnow Solution, 2013, London, England	- Winnow (2023) offers solutions for collecting, monitoring, analysing, and reporting food waste at food and beverage outlets with or without artificial intelligence (AI) support.	With the company's innovative solutions, - Food waste was cut by 50%, $46,000 cost savings, and 40,000 meals were prevented from the landfill from August 2022 to December 2022 in two Resort kitchens of Four Seasons Resort Costa Rica. - Food waste was cut by 55%, €18,000 cost savings, and 27,000 meals were prevented from the landfill in a year at Novotel Warsaw Centrum. - Food waste was cut by 70%, $65,000 cost savings, and 25,000 meals were prevented from the landfill in a year at the Hilton Dubai Jumeirah (Winnow, 2023).
Lightblue Consulting, 2012, Bangkok	-Light Blue (2023) provides technology solutions to monitor and reduce food waste and related costs.	With the company's innovative solutions, - With the Food Waste Prevention Project in Mauritius, a study was conducted with ten hotels and restaurants. As a result of the study, food waste was reduced by 43% on average, 124,295 meals (62,147 kg. food) were prevented from the landfill, and $ 209,793 was saved. - As part of the Hyatt Apac 2022 Pilot Programme, on average, 36% less food waste was generated, saving 49,020 kg of food (equivalent to 98,041 meals) and a cost reduction of £241,170. These outcomes were achieved through implementation in eight Hyatt hotels over four months (Light Blue, 2023).
Monnit, 2010, Utah, United States	- The Monnit (2023) offers technological solutions that control food storage, cooking and serving temperatures via sensors and provide real-time alerts for potential threats (temperature rise, door left open, abnormal motor activity, etc.).	Data on reducing food waste was not available.
eSmiley, 2007, Copenhagen, Denmark	- eSmiley (2023) offers digital opportunities such as self-monitoring of the kitchen, risk analysis, automatic temperature measurement, risk assessment, and food waste measurement.	With the company's innovative solutions, - Food waste was reduced by 50% at Food by Coor (eSmiley, 2023).
Lightspeed, 2005, Canada	- Lightspeed (2023) offers automated inventory management and kitchen display systemsolutions. The automatic inventory management software provides low-stock alerts, inventory management, and order automation solutions. Utilizing the Kitchen Display System software, orders are promptly	- Lightspeed (2023) expects a 40% improvement in operational processes. - Taverne Atlantic, Maynard, Recess, Five Guys, Göngfu, and Tinc Set food and beverage businesses stated that they improved their operation processes by using applications (Lightspeed, 2023).

	transmitted to the kitchen, reducing production errors while recording data on production times and systematically grouping production.	
LeanPath, 2004, Portland, US	- LeanPath (2023) offers an automated food waste collection, monitoring, and analysis technology solution combining hardware, software, and customer success programs to prevent kitchen and plate waste.	With the company's innovative solutions, - 54% reduction in food waste and prevented 61 tonnes of food waste since 2016 at the Ritz Carlton Hotel, Pentagon City. - Food waste was cut by 64% at Sheraton Grand Hotel & Spa Edinburgh. - Food waste was cut by 50% in just five months at Hilton San Diego Bayfront in San Diego, California (LeanPath, 2023). - Guy's and St. Thomas' NHS Foundation Trust's catering operations reduced food waste by 42% in eight months, preventing more than 3.5 tonnes of food (5,851 portions) from being wasted (Mansel, 2023).

Source(s): Table created by author/s.

Table 2 depicts the names, locations and dates of establishment, the purpose for which the company proposes a solution, and some of the successful results of the proposed solution for different technological solutions for non-preventable food waste. The two main methods currently used after food waste is generated are food donations and end-of-day sales. PareUp (USA), Food Loop (Germany), Optimiam (France), Justoclic (France), Mogo (USA) and Foodzor (Belgium) are software companies that mediate the sale of edible foods at discounted prices for consumers (Martin-Rios et al., 2018). Too Good To Go (2023), one of the companies analysed, is an application that allows the selling of edible food not sold that day at a low price. The application saves more than 100,000 daily meals (Mouysset, 2023). Food For All, Luse, GoMkt and Nofoodwasted are other applications that mediate the listing of unsold food (Çavuş, 2021). Zero Percent, Food Cowboy and Copia provide services such as listing donated products, liaising between stakeholders for donations, collecting and delivering donations, and tracking donated food so that donating companies can benefit from tax deductions. Copia, one of the companies examined, partnered with Getir and facilitated Getir to donate 7,485 kilograms of edible food and distribute 6,238 meals to local non-profit organisations (Hurtig, 2022). In 2020, Cheesecake Factory restaurants donated 400,000 pounds of food to non-profit organisations in partnership with Copia (Smith, 2021). In 2021, Food Cloud (2023) distributed 16,380 tonnes of surplus food (39 million meals) to charities in Ireland, the UK, the Czech Republic and Slovakia. Olio, Share the Meal, Leftover Swap, Zomato Feeding India, Transfernation, Food Rescue Us, Food Rescue Hero, and Goodr are other platforms that mediate food donations among stakeholders (Çavuş, 2021).

Table 2. Information, Aims and Achievements of Companies Offering Alternative Technological Solutions to Dispose Unavoidable Food Waste

Company Name/ Date of Establishment/ Headquartes	Company Purpose	The Success of the Company's Technological Solutions in Disposing Food Waste
SEaB Power, 2018, London, England	- The SeaB Energy's Flexibuster™ technology (2023) enables the conversion of organic waste into energy at the point where the waste is generated, and energy is required. This reduces food waste management and waste transport costs.	- A commercial bakery survey showed that the bakery's waste disposal cost was £300/metric tonne. Waste processed by Flexibuster results in a cost saving of just under £14,000 per year in disposal charges. - The installation of Flexibuster™ technology at the Continente supermarket in Portugal processes between 500kg and 3000kg of waste per day and converts it into clean energy in electricity and heat energy (SEaB Energy, 2016).
Kaffe Bueno, 2016, Søborg, Denmark	- Kaffe Bueno (2023) is Danish coffee upcycling company. It offers the possibility to recycle used coffee grounds and powder into cosmetics, hygiene products, and functional foods.	- The company makes food products such as Kaffoil and Kaffibre from used coffee grounds. - 7-Eleven restaurant & café has launched Kaffibre and Mocca buns throughout Denmark. - Kaffibre is decaffeinated, rich in protein and fibre, and 99% of the coffee grounds waste is used to produce Kaffibre (Kaffe Bueno, 2023).
Wundermart, 2017, Amsterdam, Holland	- Wundermart (2023) offers an unstaffed, self-managed smart store experience. The company's innovative solutions include utilising unused space in the hotel lobby, 24/7 accessibility, smart assortment and autonomous replenishment.	- Pardo (2021) noted that Wundermart allows well-known brands such as NH, Hilton, Radisson and Novotel to offer prepared meals and snacks to both their guests and passers-by, creating a new source of revenue for F&B departments.
Too Good To Go, 2016, Copenhagen, Denmark	- Too good to go offers an app where users can buy food at a very low price that is not sold that day and will go to the bin if not consumed (Pardo, 2021).	- Too good to go saves more than 100,000 meals a day (Mouysset, 2023).
Copia, 2016, Laguna Beach, California	- Copia (2023) provides for the measurement and analysis of food surpluses resulting from overproduction and over-purchasing, as well as for the safe donation of surplus food, which facilitates tax deductions.	- Through collaboration with Copia, Getir donated 7,485 kilograms of edible food and distributed 6,238 meals to local non-profit organizations (Hurtig, 2022). - In 2020, Cheesecake Factory restaurants donated 400,000 pounds of food to non-profit organizations in partnership with Copia (Smith, 2021).
Food Cloud, 2013, Dublin, Ireland	- Food Cloud (2023) provides technological assistance to link companies with excess food to charities and community groups in need.	- In 2021, Food Cloud (2023) distributed 16,380 tonnes of surplus food (39 million meals) to charitable organizations in Ireland, the United Kingdom, the Czech Republic, and Slovakia.
Maeko, 2011, Petaling, Malaysia	- Maeko (2023) offers a composting machine service for hotels, supermarkets, factories, schools, or other F&B businesses. The aim is to manage food waste at its source and reduce waste transport costs.	- Maeko (2023) reports that organic waste accounts for 50% of landfill waste and that 14 million kg of food waste has been successfully transformed into compost.

Oklin International, 1997, Kowloon, Hong Kong	- Oklin (2023) converts natural composting with microbial technology into nutrient-rich soil within 24 hours in an energy-efficient and automated process.	- Composting systems employing microbial technology can decrease waste volume by as much as 90%, lower disposal expenditures, and yield a nutrient-rich, reusable final product (Oklin, 2023). - Ramada and Sheraton Hotel Group utilise this technology (Esposito, 2021).
Orca, 2012, Toronto, Ontario	- Orca Biochips Technology (2023) uses air, water, and microbiology to transform food waste into an environmentally friendly liquid that can be disposed of through existing sanitation systems. Furthermore, the Orca Portal enables tracking of food waste.	- Four Seasons, Hilton, Hyatt, Marriott, Marriott, The Ritz-Carlton, Sheraton, Shangri-la, Loews hotels utilise this technology (Orca, 2023). - Especially on cruise ships, as the output is in liquid form, the water can be filtered and reused as grey water (Esposito, 2021).

Source(s): Table created by author/s.

Companies provide various technological solutions for the disposal of unavoidable food waste, including transformation into energy and new products, creative sales strategies, and innovative composting methods. SEaB Power converts organic waste into energy, reducing waste transport and disposal costs. The Flexibuster™ technology developed by the company has effectively helped reduce waste disposal costs by £14,000 annually in a single kiln. In addition, at a market in Portugal, between 500 kg and 3000 kg of food waste is processed on-site daily, transforming into energy (SEaB Energy, 2016). Kaffe Bueno converts coffee grounds into functional food, cosmetics, and hygiene products. For instance, the company uses 99% of coffee grounds to produce the Kaffibre food item. In Denmark, the 7-Eleven restaurant and café offers Kaffibreli buns rich in fibre and protein (Kaffe Bueno, 2023). Wundermart (2023) offers the opportunity to utilise unused spaces in the hotel lobby as a smart store. Hilton, Radisson, and Novotel hotels use the organisation's technology as a fresh revenue stream for takeaway meals and snacks (Pardo, 2021). Maeko (2023) provides a composting machinery service to handle waste at its origin, thereby reducing transportation costs. According to the company's report, 14 million kilograms of food waste have been successfully transformed into compost. Oklin International (2023) offers the opportunity to compost food waste within 24 hours with microbial technology. Ramada and Sheraton Hotel Group utilize this technology (Esposito, 2021). Orca (2023) presents a technology that converts food waste into water. Four Seasons, Hilton, Hyatt, Hyatt, Marriott, Marriott, The Ritz-Carlton, Sheraton, Shangri-la, and Loews hotels utilise this technology. Especially on cruise ships, because the output is liquid, the water can be filtered and reused as grey water (Esposito, 2021).

DISCUSSION AND CONCLUSION

Food waste can occur at every stage of the food supply chain, such as procurement, storage, production, and consumption, technology companies offer direct and indirect technological solutions for hotels, restaurants and catering firms to prevent food waste. In this study, the technologically innovative solutions companies offer to decrease avoidable and unavoidable food waste and their levels of efficacy were examined. Companies offer technological solutions to decrease preventable food waste both directly and indirectly. To prevent food waste directly, companies suggest technological solutions to monitor, predict, analyse and report food waste. Additionally, companies have indirect technological solutions to avoid food waste, such as precise sales forecasting, production planning, menu analysis, inventory management, production enhancement, temperature monitoring, and risk analysis. The companies' technological solutions exhibited varying degrees of success in reducing food waste. Technological interventions aimed at reducing food waste showed effective rates ranging between 30% and 70%. Companies utilising production planning technology based on sales forecasts have achieved success rates ranging from 52% to 82%. In contrast, other innovative solutions have experienced success rates of 35% to 50%. Therefore, technological options for sales and demand forecasting and production planning prove to be more effective in mitigating food waste. Alongside decreasing food waste, hospitality companies like Four Seasons Resort Costa Rica, Novotel Warsaw Centrum and Hilton Dubai Jumeirah accomplish significant cost savings from £18,000 to £65,000. The magnitude of waste in large-scale projects underscores the need to address waste in social, economic, and environmental terms. In a Light Blue project comprising ten hotels and restaurants, 124,295 meals (equal to 62,147 kg. of food) were spared from the landfill, saving £209,793. Another Light Blue project involving eight Hyatt hotels prevented 49,020 kg. of food (equivalent to 98,041 meals) from being wasted, leading to a cost reduction of £241,170. Businesses using technology also have advantages, such as lower costs, better planning, higher productivity, and improved operations. Companies' technological solutions can reduce food costs by up to 24% and labour costs by up to 20%. In addition, technological solutions result in up to a 50% improvement in sales forecasting and production planning and a 40% improvement in operational processes.

Donations of food waste and end-of-day sales are the main solutions for preventing food waste. Various intermediary organisations and software applications, including PareUp, Food Loop, Optimiam, Justoclic, Mogo, Foodzor, Too Good To Go, Food For All, Luse, GoMkt, and Nofoodwasted, are instrumental in the end-of-day sales of edible food. These companies prevent significant amounts of food from being wasted, and thereby assist in reducing overall food waste levels. For example, Too Good To Go saves over 100,000 meals daily (Mouysset, 2023). There are also numerous companies and software applications (Zero Percent, Food Cowboy, Copia, Olio, Share the Meal, Leftover Swap, Zomato Feeeding India, Transfernation, Food Rescue Us, Food Rescue Hero, Goodr) that facilitate the delivery of edible food to charitable organisations and the resulting tax deduction for businesses. These companies prevent a significant amount of food waste and assist donating businesses in benefiting from tax deductions.

For example, Getir donated 7,485 kilograms of edible food through Copia and distributed 6,238 meals to local non-profit organisations. In 2021, Food Cloud (2023) distributed 16,380 tonnes of surplus food (39 million meals) to charities in Ireland, the United Kingdom, the Czech Republic and Slovakia. Companies offer many tech solutions, such as waste-to-energy systems, composting methods, innovative sales techniques, and waste-to-new products. These applications offer significant savings in waste disposal and transport costs. For example, SEaB Power has saved £14,000 a year in a bakery by converting organic waste into energy. Kaffe Bueno recycles 99% of waste coffee grounds, producing a new and valuable product. Wundermart offers an innovative solution for the sale of surplus edible food. The companies Maeko, Oklin and Orca offer innovative composting solutions.

Consequently, the innovative solutions technology companies offer to hotels, restaurants, and catering firms successfully reduce food waste directly and indirectly. The study also found that technology solutions can help companies improve sales forecasting, production planning and operational processes and reduce food and labour costs. The study also highlighted that technology companies have different ways of dealing with unavoidable food waste, such as converting it into energy, making new products, finding new ways to sell it and using new composting methods. This study is limited to analysing data and case studies obtained from the websites of firms providing technological solutions to combat food waste, as well as relevant news articles and academic research about these firms. More experimental studies are needed, particularly on applying artificial intelligence (AI)-based technological solutions to prevent food waste at all stages of the food supply chain, including procurement, storage, production and consumption. It is also recommended that studies be carried out on the importance of converting unavoidable food waste into energy, such as water, electricity or a new product in the hotel, restaurant and catering industry and the benefits this can bring to the business.

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